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Non-LTE effects in Na I spectral lines in stellar atmospheres

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Abstract

The paper examines the statistical equilibrium of Na I in stellar atmospheres with a wide range of parameters: Teff = 4000-12 500 K, log g = 0.0-4.5, and heavy element content [A] from 0.5 to -4.0. The effect of the "overrecombination" of Na I (i.e., excess relative to the equilibrium number density of Na I) is present over the entire range of parameters considered, and increases with Teff and luminosity. Na I lines are stronger than in the LTE case, so that non-LTE corrections to the sodium abundance, ΔNLTE, are negative. Eight Na I lines commonly employed in abundance analyses are used to construct the dependences of the non-LTE corrections on Teff, log g , and metallicity. The non-LTE corrections are small only for the Na I λλ615.4, 616.0 nm lines in main-sequence stars: |ΔNLTE| ≤ 0.08 dex. In all other cases, ΔNLTE depends strongly on Teff and log g , and a non-LTE treatment must be applied if the sodium abundance is to be determined with an accuracy no worse than 0.1 dex. The profiles of solar Na I lines are analyzed in order to empirically refine two types of atomic parameters required for the subsequent analysis of the stellar spectra. In the solar atmosphere, inelastic collisions with hydrogen atoms influence the statistical equilibrium of Na I only weakly, and the classical Unsold formula underestimates the van der Waals constant C6. The empirical correction Δ log C6 is from 0.6 to 2 for various Na I lines. The sodium abundance in the solar atmosphere is determined based on line-profile analyses, yielding different results depending on whether the model atmospheres of Kurucz (log εNa = 6.20 ± 0.02) or Holweger and Muller (log εNa = 6.28 ± 0.03) are applied.